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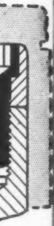

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INSTITUTION NOTES

December, 1947

The following meetings have been arranged to take place in December and January, 1948. Where full details are not given, these have not been received at the time of going to press.

December Meetings

1st YORKSHIRE SECTION. A lecture on " Modern Mining Machinery and Methods " will be given by Mr. W. Britton, M.I.M.E., at the Hotel Metropole, Leeds, at 7-00 p.m.

1st COVENTRY GRADUATE SECTION. A lecture on " The Development of the Radial Aircraft Engine " will be given by the President of the Institution, Mr. N. Rowbotham, C.B.E., M.I.P.E., on The Old Library Premises, Trinity Churchyard, Coventry, at 7-15 p.m.

2nd LONDON GRADUATE SECTION. A lecture on "Motion Study" will be given by Miss A. G. Shaw, M.A., M.I.P.E., at the Waldorf Hotel, Aldwych, London, W.C.2.

3rd PRESTON SECTION. Two short lectures have been arranged: (1) " Belt Drives " by Mr. S. M. Hardaker, M.I.P.E., and (2) " Tapping Problems " by Mr. J. Fogg, A.M.I.P.E. The meeting will take place at Messrs. Clayton, Goodfellow & Co., Ltd., Blackburn, at 7-15 p.m.

3rd NOTTINGHAM SECTION. A lecture on " Work Routing and Paper Work " will be given at the Victoria Station Hotel, Milton Street, Nottingham, at 7-00 p.m.

5th BIRMINGHAM SECTION. A Joint Meeting with the Illuminating Engineering Society has been arranged, for the purpose of a Discussion on " Industrial Lighting and Decoration," at the Imperial Hotel, Birmingham. Tea will be served at 6-00 p.m., and the Discussion will commence at 6-30 p.m.

5th NORTH-EASTERN GRADUATE SECTION. A Film Evening has been arranged, when the following films will be shown : (1) " Highroad to Production " ; (2) " Age of Precision " ; (3) " Researches in High Speed Carbide Milling."

5th PRESTON SECTION. The Annual Dinner Dance will be held at the Victoria and Station Hotel, Preston.

December Meetings—*cont.*

8th HALIFAX SECTION. A lecture on " Management " will be given by Lt.-Col. C. W. Mustill at Whiteley's Cafe, Westgate, Huddersfield, at 7-00 p.m.

8th MANCHESTER SECTION. A lecture on " Modern Mining Equipment and Its Application " will be given by Mr. R. Barker, at the Mechanics Institute, Crewe.

10th WOLVERHAMPTON SECTION. A lecture on " Lighting for Efficient Production " will be given by Mr. W. Robinson, B.Sc., A.M.I.E.E., at the Wolverhampton and Staffordshire Technical College, at 7-00 p.m.

10th SHEFFIELD SECTION. A lecture on " Engineering Applications of Polarised Light " will be given by Dr. J. Ward, B.Sc.

10th SOUTHERN SECTION. A lecture on " Light Alloy Extrusion Processes " will be given at University College, Southampton, at 7-30 p.m.

10th WESTERN SECTION. A lecture on " Incentives to Direct and Indirect Engineering Workers " will be given by Mr. K. E. Taylor, A.M.I.P.E., at Wheatstone Hall, Brunswick Road, Gloucester, at 7-15 p.m.

11th LEICESTER SECTION. A lecture on " Modern Milling Practice " will be given by Mr. W. S. B. Kidd at the College of Technology, The Newarke, Leicester, at 7-00 p.m.

11th LONDON SECTION. A lecture entitled " The Gap Between Production Engineer and Manager " will be given by Mr. W. C. Puckey, M.I.P.E., F.I.I.A., at the Royal Empire Society, Northumberland Avenue, London, W.C.2, at 7-00 p.m.

12th EASTERN COUNTIES. A lecture on " Industrial Radiography " will be given by Dr. R. H. Herz at the Britannia Works, Colchester, at 7-45 p.m.

12th COVENTRY SECTION. A lecture on " Modern Mining Machinery " will be given in Room A5, Coventry Technical College, Coventry.

13th WESTERN SECTION. A Dinner and Dance will be held at the Grand Hotel, Bristol.

13th YORKSHIRE GRADUATE SECTION. A visit to Woolley Edge Colliery, Darton, near Barnsley, has been arranged, starting at 2-30 p.m.

December Meetings—*cont.*

17th LIVERPOOL SUB-SECTION. A lecture on " Mechanical Handling " will be given by Mr. A. A. Simpson, A.M.I.P.E., A.I.Mech.E., A.I.E.E., in the Arts Theatre, Liverpool University, at 7-15 p.m.

18th GLASGOW SECTION. A lecture on " Cutting Lubricants and Coolants " will be given by Mr. H. H. Beeny at the Institution of Engineers and Shipbuilders in Scotland, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

19th HALIFAX GRADUATE SECTION. A lecture on "Precision Thread Rolling with Cylindrical Dies," illustrated by a sound film, will be given by Mr. W. A. Hawkins at the Technical College, Halifax, at 7-00 p.m.

January Meetings

5th YORKSHIRE SECTION. A lecture on " Ball and Roller Bearings " will be given by Mr. F. Huckling, M.B.E., M.I.A.E., at the Hotel Metropole, Leeds, at 7-00 p.m.

7th PRESTON SECTION. A lecture on " Induction Heating " will be given at the Harris Institute, Corporation Street, Preston, at 7-15 p.m.

7th NOTTINGHAM SECTION. A lecture on " Heavy Engineering " will be given at the Victoria Station Hotel, Milton Street, Nottingham, at 7-00 p.m.

10th NORTH-EASTERN GRADUATE SECTION. A Works Visit to Messrs. Churchill, Redman & Co., Ltd., has been arranged.

12th HALIFAX SECTION. A lecture on " Britain's Industrial Future " will be given by Mr. Lewis C. Ord at the White Swan Hotel, Halifax, at 7-00 p.m.

12th LUTON & DISTRICT SECTION. A lecture on " Press Work " will be given by Mr. Grainger at the Town Hall, Luton, at 7-00 p.m.

12th DERBY SUB-SECTION. A lecture on " Making a Typewriter " will be given by Mr. R. M. Evans in the Art School, Green Lane, Derby, at 6-45 p.m.

13th BIRMINGHAM GRADUATE SECTION. A lecture on " Mechanical Handling in Factories " will be given by Mr. H. M. King at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-15 p.m.

14th LONDON GRADUATE SECTION. A lecture on " Production Incentive Systems " will be given by Mr. A. Gordon, A.M.I.P.E.

January Meetings—*cont.*

15th GLASGOW SECTION. A lecture on "Cold Upsetting and Thread Rolling" will be given by Mr. T. C. Parker, M.I.P.E., at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

15th MANCHESTER GRADUATE SECTION. A film on "Metal Spraying," introduced by Mr. W. E. Ballard, F.R.I.C., F.I.M., will be shown at the College of Technology, Sackville Street, Manchester, at 7-15 p.m.

15th LEICESTER SECTION. A lecture on "Industrial Radiography Applied to Production Engineering" will be given by Mr. D. N. John at the College of Technology, The Newarke, Leicester, at 7-00 p.m.

15th LONDON SECTION. A lecture on "Efficiency of Machining as a Basis of Production" will be given by Dr. G. Schlesinger at the Royal Empire Society, Northumberland Avenue, London, W.C.2.

16th EASTERN COUNTIES SECTION. A lecture on "Preventive Maintenance of Machine Tools" will be given by Mr. F. H. Ward, A.M.I.Mech.E., at the Lecture Hall, Electric House, Ipswich, at 7-45 p.m.

17th YORKSHIRE GRADUATE SECTION. A lecture on "Diesel Rail Traction" will be given by Mr. R. E. Ketley, M.I.Loco.E., at the Great Northern Hotel, Leeds, at 2-30 p.m.

21st WOLVERHAMPTON SECTION. A lecture on "Production of Fine Surface Finishes" will be given by Mr. H. W. Lawton, A.M.I.P.E., at the Wisemore Schools, Walsall, at 7-00 p.m.

21st BIRMINGHAM SECTION. A lecture on "Developments in Induction Heating" will be given by Mr. E. May, B.Sc., A.M.I.E.E., M.I.Mech.E., at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-00 p.m.

21st MANCHESTER SECTION. A lecture on "Mechanical Mishaps and Their Relation to Design and Workmanship" will be given by Mr. G. E. Windeler, M.I.Mar.E., M.I. Consulting E.

21st WESTERN SECTION. A lecture on "The Various Aspects of Production" will be given by Mr. F. Nourse at the Grand Hotel, Bristol, at 7-15 p.m.

21st LIVERPOOL SUB-SECTION. A lecture on "Ball and Roller Bearing Production" will be given at the Arts Theatre, Liverpool University, Liverpool, at 7-15 p.m.

January Meetings—*cont.*

22nd HALIFAX GRADUATE SECTION. A lecture on "The Training of Apprentices" will be given by Mr. W. Pilkington, M.B.E., M.I.Mech.E., M.I.P.E., at the Technical College, Huddersfield, at 7-00 p.m.

29th GLASGOW SECTION. An Informal Discussion will be held at the Institution of Engineers and Shipbuilders in Scotland, Elmbank Crescent, Glasgow, C.2, at 8-00 p.m.

30th NORTH-EASTERN GRADUATE SECTION. A lecture on "Management" will be given by Lt.-Col. C. W. Mustill.

Personal

Mr. G. E. Bausor, A.M.I.P.E., is now in Canada, and has taken up a position with the Cockshutt Plow Company Ltd., at Brantford, Ontario.

Mr. L. L. Bott, A.M.I.P.E., has been appointed Works Manager to Messrs. Davey, Paxman, Ltd., Colchester.

Mr. J. Kemsey-Bourne, Grad.I.P.E., is now Chief Production Engineer for Trade Technical Service, Ltd., London.

Mr. P. A. Broadbent, Int.A.M.I.P.E., has resigned his position with the Ministry of Supply and is now Assistant to the Chief Engineer of Messrs. Bryant and May, Ltd., London.

Mr. K. Brown, Grad.I.P.E., is joining the Assam Oil Co., Ltd., India, as Engineer-Driller.

Mr. F. Deakin, Int.A.M.I.P.E., is now Instructor in the Drawing Office Training School recently established by the Wellman Smith Owen Engineering Corporation, Ltd., Darlaston.

Mr. E. R. Eccles, Grad.I.P.E., A.M.I.Mech.E., Chairman of Yorkshire Graduate Section, has resigned his post as Lecturer in Mechanical Engineering at the Mining and Technical College, Barnsley, to take up a similar position at the Municipal Technical College, Halifax.

Mr. A. D. Granger, A.M.I.P.E., has taken up a position as Consulting Engineer with Associated Industrial Consultants, Ltd.

Mr. F. Hardy, A.M.I.P.E., is now with the Anglo-Iranian Oil Co., Ltd., London, as a Lubricating Engineer.

Mr. N. Ingham, Grad.I.P.E., is going out to Iran as Assistant Mechanical Engineer (Production) to the Anglo-Iranian Oil Co., Ltd.

Mr. R. W. P. Johnson, Grad.I.P.E., is now Instructor in Engineering Drawing at the University of Toronto, Canada.

Mr. A. Lowson, Grad.I.P.E., has now been demobilised, and has rejoined Messrs. Douglas Fraser & Sons, Ltd., Arbroath, as a Jig and Tool Draughtsman.

Mr. L. W. J. Lait, Int.A.M.I.P.E., is now with the National Forgemaster's Association at the Central Office in Sheffield.

Mr. R. Nelson, Grad.I.P.E., is now Senior Time Study Engineer with Messrs. A. V. Roe (Canada) Ltd., Malton, Ontario.

Mr. S. T. Piggott, M.I.P.E., is now Production Manager in the Wimet Division of Messrs. A. C. Wickman, Ltd., Coventry.

Mr. F. Reaves, M.I.P.E., has taken up a position as Works Manager of Messrs. Rotary Hoes, Ltd., East Horndon, Essex.

Mr. R. B. Williams, Grad.I.P.E., is in charge of the Plant and Maintenance Drawing Office of Jarrow Tube Works, Ltd., and not, as reported in the October *Journal*, in charge of the Plant and Maintenance Drawing Office of the Parent Company, the Tubes Investments Group.

Mr. L. G. Wise, A.M.I.P.E., is now Head of the Engineering Department at Gateshead Technical College.

Mr. T. C. Winmill, A.M.I.P.E., has resigned his position of Manager with Measuring Instruments " Pullen " Ltd., on account of illness.

Mr. S. Wright, B.Sc., M.I.P.E., Member of Council, has joined Messrs. Armstrong-Siddeley Motors, Ltd., Coventry.

Obituary

We deeply regret to announce the death of Mr. A. B. Townsend, M.I.P.E., of Sheffield Section.

Lord Austin Prize—Revised Conditions of Award

The conditions for the Lord Austin Prize have been amended to read as follows :—

" Graduates up to the age of 28 years will be eligible to enter for the Lord Austin Prize, but may only be *awarded* the prize once during their term as Graduates."

The new conditions will come into effect for the 1948 competition.

Books Received

Factory Costing and Organisation by H. H. Emsley, B.Sc. (Eng.) and J. Loxham, M.I.M.E., M.I.P.E. Published by Constable & Son, London. Price 7s. 6d.

This book has been written as a text-book for students concerned with workshop production in relationship to Factory Costing and Organisation. The book takes the student by easy stages through the elements of costing, the methods of building up cost figures,

and the internal organisation necessary to enable efficient control to be established. It is very well set out and useful information is given on the linking-up of the cost system and the use of cost data necessary for the efficient control of an industrial organisation.

What's Wrong With Your Factory, Office or Works? by W. A. Melhuish, A.M.I.P.E. Published by George G. Harrap & Co., Ltd., London, Price 15s.

The scope and objects of this book are best indicated by the following quotation from the author's preface :

" Even in these days of so-called highly organised business enterprise and productive achievement there can be found at any one moment large numbers of harassed business men, owners and directors, whose outstanding problem is to discover some means of ascertaining just what is wrong with their factories and workshops, and how to commence to put things right."

The author then states :—

" The chosen method of approach is the recounting of examples of methods which have been used with success in a large number of factories of varying sizes in a number of different types of manufacture both in Great Britain and overseas."

The examples given are interesting and the whole book, which is well produced, is worthy of the attention of those interested in the subject of industrial efficiency.

Issue of Journal to New Members

Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

Important

In order that the Journal may be despatched on time, it is essential that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

REPORT OF ANNUAL GENERAL MEETING

Thursday, 30th October, 1947.

The Twenty-Sixth Annual General Meeting of the Institution was held at the Institution of Civil Engineers, Great George Street, London, S.W.1 on Thursday, 30th October, 1947, at 3.30 p.m. Mr. N. Rowbotham, C.B.E., President, occupied the Chair.

1. Notice Convening Meeting.

The Director & General Secretary (Major C. B. Thorne, M.C.), read the Notice convening the Meeting.

2. Minutes.

The Minutes of the previous Annual General Meeting, which had been circulated, were taken as read, and were confirmed and signed.

3. Election of Members of Council.

The Director & General Secretary read the list of Officers and Members of Council for 1947/48, as at 1st July, 1947.

4. Presidential Address.

The President of the Institution, Mr. N. Rowbotham, C.B.E., B.Sc., Wh.Ex., F.R.Ae.S., M.I.M.E., M.I.P.E., gave the following address:

"A little more than twelve months has elapsed since our last Annual General Meeting, and during that time the importance of Production Engineering has been accentuated. From every platform we are told of the necessity for increasing production, and we are warned that unless this increase is forthcoming, not only our standard of life but our very existence is threatened. All classes of the community are being invited, cajoled and wheedled into increasing output, while in the same breath we are told that the major portion of our output must be exported in order to pay for the things upon which our life depends.

"I suppose that there is not one of us here who can view the present, and perhaps still more the immediate future, with anything other than grim determination. The deliberations of the Council of the Institution today have afforded ample proof that they intend to do all in their power to assist the nation to overcome this crisis.

"In our individual lives, according to our respective circumstances, we examine the problems before us and we cannot but recognise the handicaps from which we suffer at the moment. We are faced with inadequate coal supplies—a matter which has been well ventilated at the Council Meeting today—power cuts, material shortages, and last but certainly not least, the reduced working week and, I am afraid, the reduced energy which is put out during that working week. These are factors which will tax the most courageous

of us. Planning, mechanisation, and similar aids, excellent as they are in more normal circumstances, are rather dull-edged weapons with which to overcome many of these fundamental restrictions, which cut at the very roots of our production.

"Where does the Institution stand in regard to this major problem of self-preservation? I believe that much can be done, and good results can be achieved, by more intimate and more frequent meetings in the districts.

"I think that this was confirmed by the deliberations of the Council today, and the Conferences which have been and are being organised in the provinces show the way, in my opinion, in which this Institution can best help to solve our national problem. Greater results can be obtained in the forum of lecture and debate, and by His Majesty's Government drawing their own conclusions from the views there expressed, than by seeking out Government officials in their offices and trying to tell them what ought to be done. Already some of our Sections have very enthusiastically organised meetings at which papers and lectures will be given, and I reiterate that it is in this way that we can make the best contribution to the national effort.

"Over the years the status of the Production Engineer has certainly improved. Many of us can remember the days when he was considered to be a very lowly and humble member of the engineering fraternity. In recent years the outlook has changed, and at the present time he is an individual of considerable importance; as a matter of fact, with all the production that is required, I believe that he now ranks amongst the foremost engineers.

"In some earlier remarks I commented on the desirability of attaining Charter status, and I believe that we are making progress in that direction. I have had the opportunity of discussing this matter in various quarters, and I believe that with the raising of our standard of membership, and if we arrange, in our various Sections, for syllabuses of merit and papers of the calibre we desire, then sooner than many of us may have thought we may attain the status of a Chartered Institution.

"In research, our contribution should be objective and progressive. The essential foundations on which a good research structure can be built are not easy to acquire, and certain limitations may have to be suffered due to finance. That is to be deplored, but it is one of those practical considerations which may determine the scope and extent of our research work.

"In education, many of the Technical Colleges are now putting production engineering subjects into their curricula. Having decided

to appoint an Education Officer, the Institution should now be in a position to assist in the extension of these activities, and we should therefore ultimately be able to train more and better production engineers.

"The question of a Convention has been mooted, and certainly those who have visited America and who have attended some of the Conventions there know the good that ensues from them and the intimate feeling they engender amongst those with common interests. We have a Committee which is examining this problem, but the present difficulties of travel, petrol restrictions and food shortages make action far from easy. However, if it is decided to hold a Convention here I hope that any lack of physical comfort will be more than compensated for by the spiritual warmth and enthusiasm of the members. Unless the support of the majority of our members is forthcoming, it would obviously be exceedingly difficult to make such an undertaking successful in all the Sections.

"I must not sit down without making a few remarks concerning our Headquarters Staff, and particularly Major Thorne, our Director and General Secretary. He and his staff have done excellent work, particularly during the past year, and I hope that a place will be found in Agenda to enable us to express our congratulations and thanks to them."

5. Annual Report.

The Chairman of Council (Dr. H. Schofield, C.B.E.) presented the Annual Report of the Council for 1946/47, which was published in the October 1947 issue of the Journal. The Report was adopted on the motion of the Chairman of Council, seconded by the President.

6. Accounts.

The Chairman of Council then presented the Accounts for the year ended 30th June, 1947, which were also published in the October Journal. He had very much pleasure and not a little confidence in so doing. The Income & Expenditure Account showed an excess of income over expenditure of £1,204 10s. 7d. He moved the adoption of the Accounts. The President seconded the motion, which was carried unanimously.

7. Election of Auditors.

On the motion of Mr. E. J. H. Jones M.B.E., seconded by Mr. H. J. Swift, O.B.E., Messrs. Gibson, Appleby & Co., Chartered Accountants, were re-elected Auditors to the Institution for the year 1947/48.

8. **Election of Solicitors.**

On the motion of Mr. E. P. Edwards, seconded by Mr. J. T. Kenworthy, Messrs. Syrett & Sons, of Lincolns Inn, were re-elected Solicitors to the Institution, for the year 1947/48.

9. **Votes of Thanks.**

The president moved a vote of thanks to the Section Honorary Secretaries, and said that probably few members realised the immense amount of work carried out by those hard-working officers. He also moved a vote of thanks to the Director & General Secretary and the Headquarters staff, saying that the Institution was greatly indebted to Major Thorne and his staff for their good work and continued loyalty. Mr. A. W. Buckland, who seconded the vote of thanks, said that he did so with great pleasure.

The vote of thanks was then carried unanimously, with acclamation, and on the motion of Mr. E. P. Edwards, it was agreed that a special letter of thanks, over the President's signature, should be sent to all Section Honorary Secretaries.

Mr. H. J. Swift O.B.E. moved a vote of thanks to the President and the Chairman of Council. He said that the Institution had every reason to be grateful to Mr. Rowbotham for his work as President, and in referring to the Chairman of Council, he felt that Dr. Schofield got through the large agenda at Council meetings in the most excellent manner. Mr. J. E. Attwood seconded the motion which was carried unanimously, with acclamation.

The Chairman of Council expressed his own thanks and those of the President. It was a great compliment, he said, to have the honour of being chairman of the Council. He had very much enjoyed his work, and was very pleased that it had met with approval.

The Director & General Secretary, who also responded, thanked the meeting for the compliments paid to Headquarters, and said that the enthusiasm which was shown by the staff had been stimulated by the members of the Institution ; the loyalty which members received from Headquarters was inspired by themselves. It was a great pleasure to have the privilege of serving such a magnificent body, and he hoped that the Institution would become the organisation for which they were all striving.

The Annual General Meeting then terminated.

[illegible]

SURFACE FINISH MEASUREMENT OF ENGINEERING COMPONENTS

By C. TIMMS, M.Eng., A.M.I.Mech.E., A.M.I.P.E.*

Presented to the Institution of Production Engineers, Glasgow Section, January 16th, 1947 ; *Luton and District Section, February 12th,* 1947.

During the past few years, the work carried out at the National Physical Laboratory on Surface Finish Measurement has entailed the examination of a wide variety of components ranging from cellophane sheets to marine propellers. The interest in surface measurement has been stimulated by the development of stylus types of instrument capable of recording to a high scale of magnification the surface irregularities which hitherto have been assessed by practical workshop methods such as a finger-nail test or by visual appearance.

Whilst the latter methods may on a comparative basis provide some indication of the degree of roughness of a surface, they cannot measure the depth or record the shape of the irregularities. It is this feature, common to stylus instruments, which has attracted the attention of engineers and aroused considerable interest in this subject in most branches of engineering practice.

In order to study the effect of different degrees of finish in relation to the functioning of a component, instruments must first be available for recording and measurement of the irregularities and secondly, methods must be established for the assessment of the results obtained. With regard to the former, the design of the instrument is controlled to some extent by the particular type of surface irregularity it is desired to measure, i.e., fine surface texture or general surface waviness, and also by the size of the component. For large components such as marine gears and ship propellers, portable instruments have been found to be most suitable, since they can be directly applied to the work on site. In this connection it is probably true to say that the measurement and recording of surface irregularities present no great difficulty to-day, the major problem being associated with the analysis and assessment of these results. Even though a complete solution to this problem has yet to be formulated, it is considered that the use of the Average Index Number forms a practical basis for assessment, providing due allowance is made for its particular geometric limitations.

The object of this paper is an attempt to broaden the outlook of surface measurement by considering the measurement and analysis of surface irregularities which have been found to be of practical importance.

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Surface Irregularities

When specifying the general dimensions of any component it is normally assumed that its boundaries are smooth and of simple geometric form, yet in practice a machined surface always deviates from absolute perfection in this respect. These imperfections consist of a series of minute hills and valleys distributed along the surface profile, forming a pattern or texture which in some instances is characteristic of the machining process used. Such texture can, in general, be seen or felt and it can quite conveniently be divided into two general groups.

(a) Tool Texture

The irregularities associated with the machining process and arising from the cutting or abrading action of the tool. This is known as Tool Texture. Irregularities coming within this range are in general of minute depth and of comparatively short wavelength.

(b) Machine Texture

In addition, other irregularities of much longer wavelength may be present in a surface. These arise from machine vibration, tool chatter, or may even represent a relic of some previous machine operation not completely removed in the final finishing process.

In general, both types of texture are present in a surface and they blend together forming a surface pattern which in some instances is difficult to analyse. Although there is no rigid line of demarcation between Tool Texture and Machine Texture, for purposes of measurement and simplification of the instrument design it is convenient to draw some distinction between them. For example, instruments designed primarily for the measurement of tool texture in general have a traverse length not exceeding ¼-in., and for the examination of machine texture the instrument traverse may extend up to several inches.

Graphical Representation of Tool Texture

In recent years qualitative methods of assessment of the degree of finish have been supplemented by direct measurement of the irregularities. For the measurement and recording of the latter, it is now common practice to use stylus types of instruments which employ a diamond exploring probe with a tip radius of approximately 0.0001 in. The vertical movement of this probe in following the surface irregularities is amplified mechanically, electrically, or by pneumatic means. In this connection it is of interest to note that all three methods of amplification have been incorporated in different instruments developed in this country, i.e., Tomlinson

micro-finish recorder (mechanical), N.P.L. Talysurf instrument (electrical), Messrs. Taylor, Taylor & Hobson Topograph (pneumatic), Messrs. D. Brown & Sons.

An enlarged view of the exploring probe and skid attachment of the Talysurf instrument is illustrated in Fig. 1. The skid which is shown positioned in front of the diamond probe has a radius of about 1 inch, and its function is to provide a reference datum for the measurement. Since the skid radius of curvature is large compared with the tip radius of the exploring probe, it tends to bridge across the fine surface texture. Thus, during traverse of the complete unit across a surface, the vertical displacements of the probe are made relative to the skid. From strict geometrical considerations the skid radius will tend to follow to some extent the depth of the irregularities, but in general these departures are extremely small and can for practical purposes be neglected. A skidless type of pick-up unit has been developed by Messrs. Taylor, Taylor & Hobson, and it is extremely useful when measuring the finish of very small components, such as pivots for precision mechanisms.

A general view of the Talysurf instrument is shown in Fig. 2. This instrument, in addition to providing an autographic chart record of the irregularities to an enlarged scale of magnification, also measures the arithmetical average of the irregularities. The numeric assessment is obtained electrically and given in terms of a meter reading.

For a graphical representation of the tool texture variations it is necessary to employ relatively high scales of magnification normal to the surface, ranging from 2,000x to 40,000x. In a direction parallel to the surface the magnification is, for practical convenience, very much less and rarely exceeds about 200x. For example, assuming the instrument has a traverse length of ¼-in., a horizontal magnification of only 1,000x would require a chart 250 inches in length. For this reason, therefore, the two scales in the horizontal and vertical directions differ widely and the distortion ratio between the scales may vary from 10 to 800.

When estimating the shape of surface irregularities from profile records of this type, due allowance must be made for the graphical distortion ratio employed. Some ideas of the distortion effect is illustrated in Figs. 3A and 3B. The record Fig. 3A represents the normal type of profile graph taken with the Talysurf instrument and shows the cross-sectional profile of a series of etched grooves on glass. The grooves are spaced at intervals of 0·005 in. and their depth is very closely 0·0001 in. (100 micro-inches). With this record the vertical and horizontal magnifications are 4,000x and 50x respectively, thus giving a distortion ratio of 80. The record in Fig. 3B shows the cross-sectional profile of one of these grooves magnified 4,000x in both directions and, excluding the slight round-

ing effect due to the finite radius of the probe, it represents the actual shape of this particular groove. By comparing the two records, the true effect of the graphical distortion is at once apparent.

It has been stated that a diamond exploring probe cannot in practice be sharp enough to penetrate right to the roots of the extremely fine scratches. There is little doubt that for the finest finishes this is quite true, but for practical purposes the question is rather to what extent are the results inaccurate for this reason. Experience with the probe type of instrument shows that this objection carries no serious weight for ordinary machined finishes since the angle of slope of the scratches rarely exceeds about 15°. A stylus with a tip radius of 0·0001 in. is shown to the same scale as the record in Fig. 3B, and there is little doubt in this case that the probe does penetrate to the root of the groove.

Assessment of the Tool Texture using Stylus Instruments.

In order that a comparison between different finishes can be readily ascertained and quoted on production drawings, there is definite need for a simple numeric assessment of the finish in terms of a single number, similar to Rockwell or Brinell numbers used in hardness measurements. In the quest for a rational number a variety of methods can be suggested, each purporting to measure specific elements of the surface geometry[1]. Some of the more well-established methods are described below and reference is made to their limitations.

In order to measure the degree of finish numerically from a profile record, some reference or datum plane must be established from which the measurements can be made, and it is in the selection of a convenient reference plane that difficulties in measurement arise.

Two reference planes might be considered, one grazing the crests of the irregularities and the other the roots and to assess the finish as the normal distance between these two planes. For a surface with a reasonably uniform scratch depth, no difficulty would be experienced in positioning each reference plane. A surface fulfilling these conditions is illustrated by record A in Fig. 5. This represents the cross-sectional profile of a diamond-turned surface, the direction of traverse of the stylus instrument being at right angles to the feed marks. The same ease and certainty of positioning the two planes would not be possible when considering record B in Fig. 5, which represents a type of finish characteristic of plain cylindrical grinding.

Whilst this method provides some indication of the full scratch depth, no account is taken of the pitch or wavelength of the irregularities. It is possible for two surfaces to have the same scratch

depth, yet the pitch of the respective irregularities may be quite different. Two surfaces fulfilling these conditions would quite obviously have different rates of wear.

The reference planes above may also be defined as the centre-line, such that the area enclosed by the curve above this line is equal to the area enclosed by the curve below the line. For example, referring to Fig. 4, let XY represent the centre-line drawn parallel to the general direction of the surface profile, then the summation of areas a_1, a_2, a_3, etc., is equal to the summation of areas b_1, b_2, b_3, etc.

The Average Index Number in micro-inches =

$$\frac{a_1 + a_2 + a_3 + \ldots\ldots\ldots + b_1 + b_2 + b_3 \ldots \times 10^6}{M \times L}$$

where M = vertical magnification.

L = length of record selected for measurement, in inches, and a_1, b_1, etc., are in square inches.

Such a measurement may be determined from a profile record with the aid of a planimeter. This process of measurement is extremely slow and tedious to carry out, but with the aid of modern electrical instruments the measurement can be readily and quickly effected in terms of a meter reading. Some reference to the essential features of this measurement are well worthy of mention :

(*a*) The number obtained is known as the Average Index Number of the finish, and is denoted by the symbol $H_{ave.}$

(*b*) It is expressed in micro-inches, where one micro-inch equals 0·000001 inch.

(*c*) It represents the average departures of the minute hills and valleys measured, regardless of sign, with respect to the centre-line XY in Fig. 4.

(*d*) This number should not be confused with the value representing the maximum depth of the surface irregularities.

(*e*) The ratio between the Average Index Number and the maximum depth measurement may vary from about 1/3 to 1/7, depending on the shape of the surface irregularities.

(*f*) Referring to Fig. 4 it will be seen that the number is related to the length (L) of the surface selected for measurement.

(*g*) When specifying the finish in terms of the Average Index Number the length factor (L) should also be quoted.

(*h*) The number is not related to the shape of the surface irregularities and it is possible for surfaces finished by different machining processes to have the same value. A typical example of this effect is illustrated by the two curves in Fig. 5, representing a diamond-turned and a ground surface respectively; each have the same Average Index Value, *i.e.*, 9 micro-inches.

It is from this aspect that serious criticism has been levelled at the choice of the average value as a method of assessment. In spite of this limitation, however, it is considered that the value can provide a useful basis for the measurement of the finish providing it is associated with its appropriate length factor and also related to a profile record of the surface.

Importance of Tool Texture Variations in Relation to Conditions of Service.

While instruments are available for recording and measuring the fine surface irregularities, it does not follow that the smoothest finish is always the most desirable. For example, on brake drum surfaces a certain degree of roughness is essential in order to promote friction, yet on the other hand, for gas-tight, metal to metal joints, the mating surfaces must be smooth and of correct geometrical form. Again, if the working surfaces are exposed to dust and corrosive agents due to unavoidable service conditions as exists in locomotives, the initial finish may have little significance. From these brief remarks it will be evident that the quality of finish required must be very carefully considered in relation to the functioning and service conditions of the component. In addition, the finish is only one of many factors which may affect the functioning of the component. The geometric truth of a component is clearly of importance, e.g., a gear may be incorrectly mounted and it may have errors in tooth spacing and tooth form. It is also a well-established fact that if the heat-treatment of a part is not correctly carried out, a surface which was originally true could go out of truth in service. Lack of attention to these two factors may be sufficient to outweigh the need for a close control of the surface finish.

In some instances, the control of the final finishing process automatically provides sufficient control of the surface quality and the need for accurate measurement of the fine irregularities is thus avoided. There are, however, many cases in engineering practice where it has been found essential to control the finish within a specific range of roughness and the use of measuring equipment for this purpose is obviously desirable. A typical example is illustrated in Fig. 6, which shows the upper and lower limits of roughness (Tool Texture) on an aero-engine cylinder sleeve bore, indicated by curves A and B respectively. In practice it has been established that if the roughness is greatly in excess of curve A, break-down in the oil film occurs, giving rise to excessive wear of the sleeve bore. On the other hand, if the surface is too smooth, i.e., less than curve B, the rate of wear may still be excessive. An explanation suggested for the latter is that a certain amount of roughness is desirable, as the local crevices form oil-retaining pockets and thereby facilitate

lubrication, i.e., the surface cannot be wiped free of oil so easily as a perfectly smooth surface. For controlling the range of roughness in production, the use of the Average Index Number for this work has been found invaluable. Having established the final finishing operation, which consisted of a relatively coarse lapping process, little difficulty was experienced from excessive wear provided the Average Index Number of the surface irregularities was controlled between about 16 and 35 micro-inches.

For precision gauge blocks, however, extremely smooth surfaces are very desirable ; this applies especially to inspection and reference slip gauges. Two examples of the finish attained on finely lapped surfaces are illustrated in Figs. 7 and 8 by the well-established method of optical interference[2]. The former shows the average finish attained on a workshop grade of block gauge and the latter the finish of a specially lapped block.

For measurement by optical interference, the main requirements consist of a microscope suitable for vertical illumination, a cylindrical lens, and a source of monochromatic light such as a sodium-vapour or a mercury-vapour discharge lamp, used if necessary with an appropriate filter. This method is extremely suitable for the examination of the finish of slip gauges or similar worked surfaces.

Measurement of Machine Texture using Stylus Instruments.

In addition to the measurement of the fine surface texture, the inspection of finish may be complicated by the presence of other irregularities having a pitch or wavelength greater than the tool texture variations. These irregularities are generally associated with varying conditions of the machine traverse and the wavelength may vary from about 0·1 in. up to 1·0 in.

In order to measure the amplitude and study the periodic nature of these variations, it is necessary to traverse across several cycles of the waveform. With the types of surface recording instruments already referred to, this is not in general possible, due to the restricted traverse length which does not exceed about ¼-in. Further, these instruments cannot readily be applied for the examination of large components. For this class of work, portable equipment has been found to be the most suitable.

For the examination of the finish of machine beds, surface plates or journal bearings, the portable instrument illustrated in Fig. 9 may be used. This instrument, which has been fully described in a previous paper[3], employs a direct mechanical method of magnifying the machine texture variations and records them on a smoked glass plate. The mechanical amplification used is about 40x, which is increased to 2,000x when the record is examined at the screen of a projector, with an optical magnification of 50x. The exploring

probe consists of a $\frac{1}{16}$-in. diameter steel ball which passes over most of the fine tool texture but picks up the more coarsely pitched irregularities. The maximum traverse length is about 2 in.

The two records in Fig. 10 exhibit different surface characteristics on an external cylindrical turned surface. The upper record which was taken with the portable recorder (Fig. 9) shows the general waviness of the surface, excluding the fine surface texture over a length of 1 in., whilst the lower one taken with a Talysurf instrument represents the fine surface irregularities over a length of about 0·06 in. When comparing these two records, due allowance must be made for the great difference between their horizontal scales and also for the difference between the radii of the probes used. When assessing the effect of finish on the functioning of a component, it will be evident that account must be taken of the machine texture variations in addition to the tool texture variations.

In connection with gears for marine turbine reduction drives, the actual load per inch of face width may well exceed the normal design load due to the inferior finish of the tooth surfaces. These gears are in general produced by hobbing and the periodic errors in the gear-cutting machine are imprinted on the gear being cut and form an undulatory pattern along the tooth flanks. This pattern may consist of several undulations of different wavelength and amplitude, each arising from a particular periodic error in the main driving mechanism of the gear machine. A method of analysing these periodic errors and their effect on a hob cut gear has already been fully described in a recent paper[4], read before the Institution of Mechanical Engineers.

For the measurement of the amplitude and wavelength of these undulations, the instrument shown in Fig. 11 was designed. Full details of this instrument are also given in the same paper, but briefly its mode of operation is as follows :

The instrument consists of two ball feet which can be set at any convenient pitch and interspaced by a pivoted exploring ball. The exploring ball operates a recording arm arranged to scribe on a smoked glass disc which is rotated by the movement of the instrument along the gear being measured. The outer balls contact both flanks of the teeth, thus forming a register for the instrument while the centre exploring ball can be arranged to bear on either flank as desired. A typical record taken with this instrument is shown in Fig. 12. The depth of the undulations are shown magnified 200x and the length of the record corresponds to a traverse length of about 6 in. Since the exploring ball is about $\frac{5}{16}$ in. in diameter, it will be evident that this record cannot reveal the tool texture variations associated with the cutting action of the hob.

These undulations are a frequent source of trouble with marine gears, causing excessive local surface stress with possible scuffing

of the tooth surface due to local breakdown of the oil film. Further, if the crests of the undulations are parallel to the gear axis, they may give rise to acceleration and deceleration as the mating teeth move through the zone of contact and the advantage of a helical tooth form is, therefore, reduced.

During the war most countries adopted the use of camouflage paint for aircraft and one of the main requirements was that the paint should be matt, which entailed a certain degree of physical roughness. A study of the effect of surface roughness on the performance of aircraft has been carried out at the Royal Aircraft Establishment, Farnborough[5].

The measurement of the paint surface was carried out with the instrument illustrated in Fig. 13, which was developed at the N.P.L. for this purpose. This instrument is of portable construction and is arranged to conform to the changing curvature of the aerofoil as it is traversed by hand across the surface. For this purpose the sole plate of the instrument is made of flexible steel strip which contacts a similar strip wrapped round the aerofoil surface as shown in Fig. 13. The function of the latter strip is to provide a relatively smooth reference surface for the measurement.

The recording mechanism consists of a simple lever system attached to the sole plate. An exploring probe forms one arm of the lever. Its vertical displacement relative to the main steel strip is amplified mechanically 20x and recorded on a smoked glass plate by means of a scribing point attached to the other arm of the lever. The exploring probe contacts the paint surface through a central slot in the steel strip. During traverse of the instrument across the surface the smoked plate is moved at a reduced speed and the scribing point records on the plate the paint surface irregularities. This instrument has a maximum traverse of about 9 in. In addition to the measurement of aerofoil surfaces, it has recently been used for measuring the roughness of marine propellers. The record on the smoked plate is magnified optically and examined directly at the screen of a projector. In this way it is possible to take a direct photographic print of the image formed at the projector screen.

Comparative Methods of Surface Measurements.

So far attention has been mainly confined to the use of stylus recording instruments, but in addition there is definite need for some simple and inexpensive equipment which can be readily applied by the workshop personnel. To meet this need, use is often made of optical comparison microscopes for comparing the appearance of a surface against a master specimen. Instruments of this type provide a pictorial view of the surface, but they cannot measure the depth of the irregularities.

A simple measuring tool has been developed at the N.P.L. for comparing the tool texture of a component against a master specimen finished by the same process. The degree of finish of the master specimen is previously determined by one of the standard types of stylus instrument, such as a Talysurf instrument.

The instrument is in general principle a stethoscope adapted as a simple and sensitive comparator for determining the variations in tool texture of any two or more surfaces prepared by the same process. It consists of a stand type of crystal cartridge normally used for sound recording purposes. The crystal is fitted with a sharply pointed exploring probe and is connected in series with a pair of head-phones. By traversing the exploring probe across a surface, the sound produced by the crystal is transmitted to the head-phones. From a series of experiments carried out on different ground surfaces, previously measured by a Talysurf instrument, it was established that the pitch of the sound produced was approximately proportional to the degree of roughness. By connecting a potentiometer, range 30,000 ohms, across the head-phones, the sound produced can be attenuated to suit the degree of roughness of the surface.

In use, the component to be examined is placed alongside the standard surface and the difference in sound produced when the stylus is gently traversed along each surface provides a measure of the difference in roughness between the two parts. Using this method, it has been found possible to differentiate between two lapped surfaces having Average Index Values for 1 and 2 micro-inches respectively. Again, when carrying out further tests on three ground cylindrical components no difficulty was experienced in grading the surfaces in the correct order of roughness. The Average Index Values of these surfaces when measured by the integrating meter attached to the Talysurf instrument were $1\frac{1}{2}$, $4\frac{1}{2}$ and 10 micro-inches.

For general use in the workshops, it would be possible to make up standard reference surfaces corresponding to the upper and lower limits of roughness which from functioning considerations have been found desirable. These standards must be prepared in identically the same way as the components it is desired to control. As an alternative it may be possible to select two components from a batch being machined which would correspond to the upper and lower limits of roughness.

This comparator was found suitable for surfaces ranging from about 1 micro-inch up to about 20 micro-inches (H_{ave}).

The work described above has been carried out as part of the research programme of the National Physical Laboratory, and this paper is published by permission of the Director of the Laboratory.

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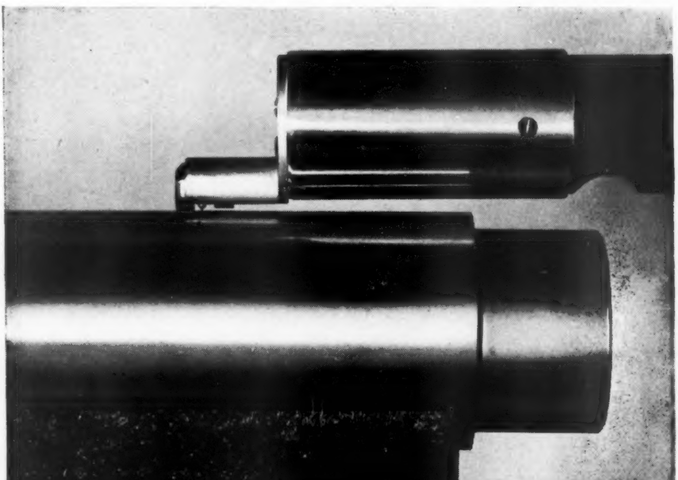


FIG. 1. View of exploring probe and skid attachment.

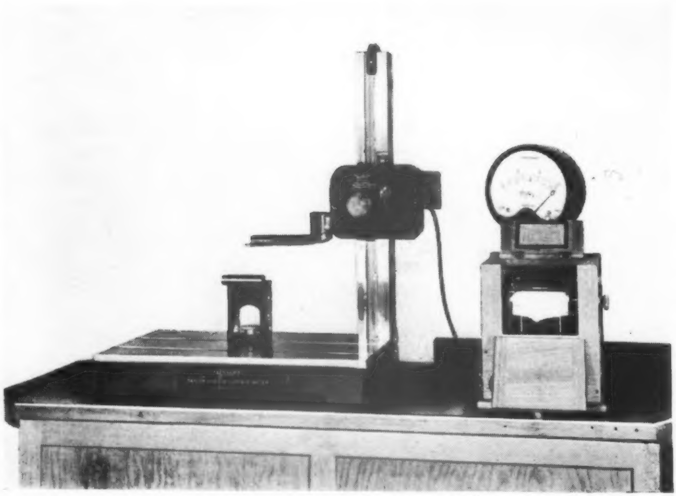


FIG. 2. General view of Talysurf Instrument.

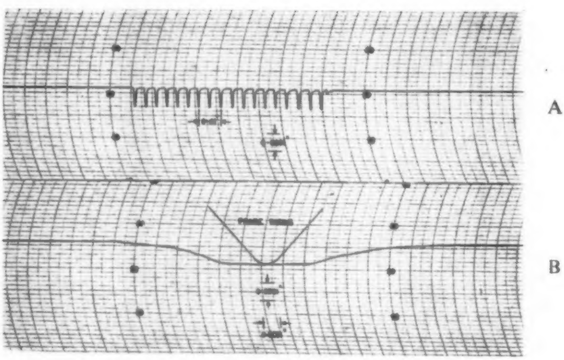
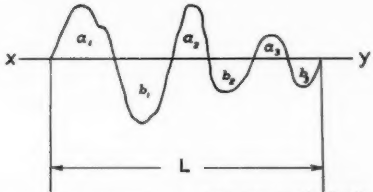


FIG. 3.



AVERAGE INDEX NUMBER (H_{AVE}) IN MICRO-INCHES. $= \dfrac{a_1 + a_2 + a_3 \text{ - - -} + b_1 + b_2 + b_3 \text{ - -}}{M \times L} \times 10^6$

a_1, b_1 ---- IN SQUARE INCHES
L ---- IN INCHES
M = VERTICAL MAGNIFICATION
ONE MICRO-INCH = 0·000001"

FIG. 4.

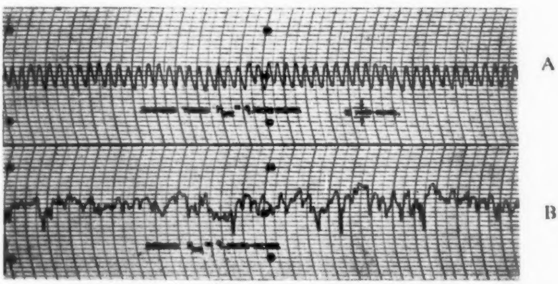


FIG. 5.

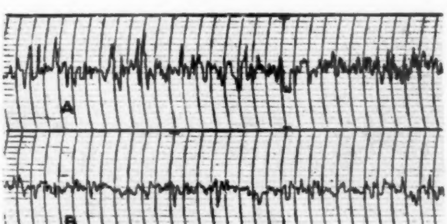


FIG. 6.

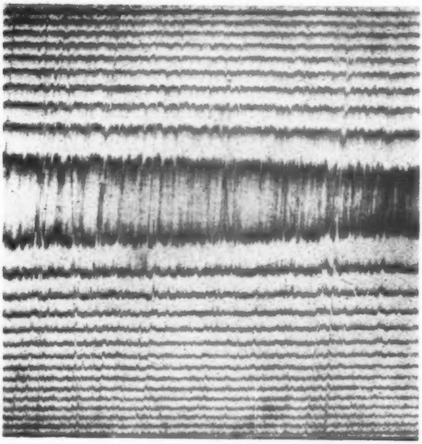


FIG. 7.

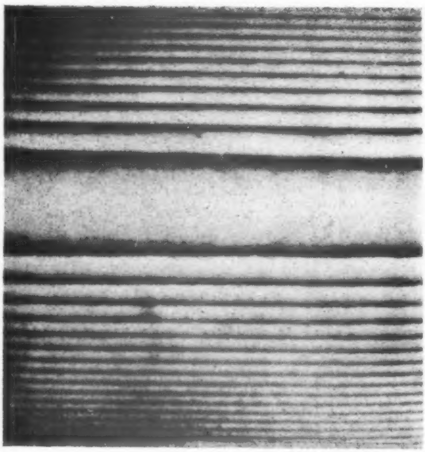


FIG. 8.

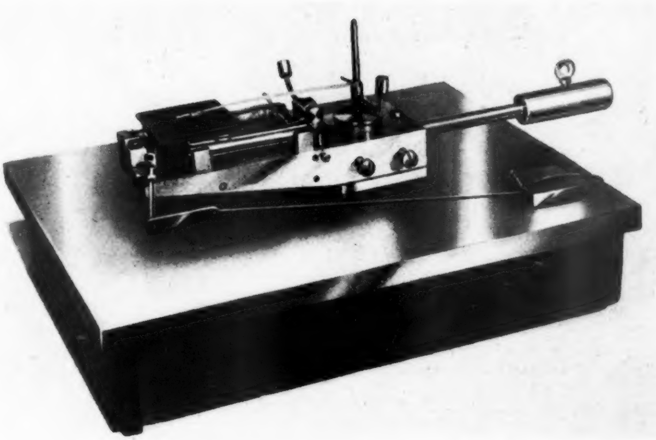


FIG. 9. Waviness Recorder.

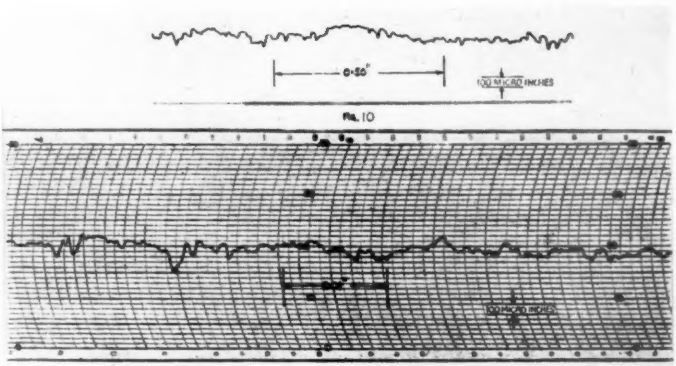


FIG. 10. Profile records showing machine texture and tool texture irregularities.

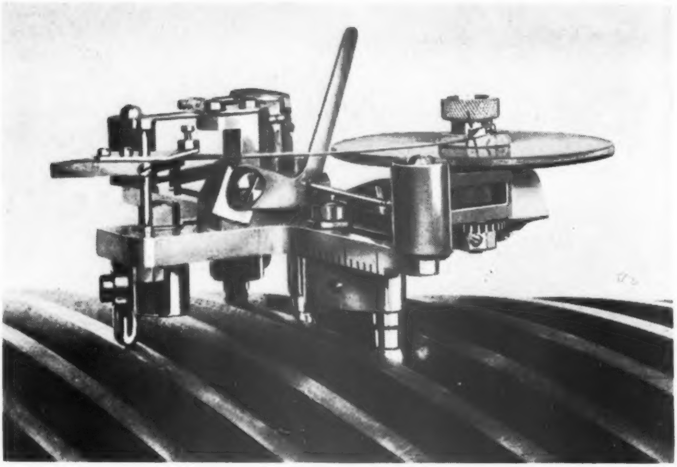


FIG. 11. Gear tooth undulation recorder.

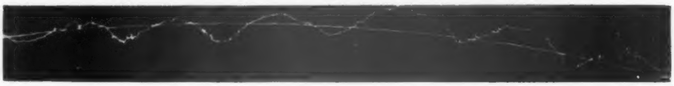


FIG. 12. Typical gear tooth undulation record.

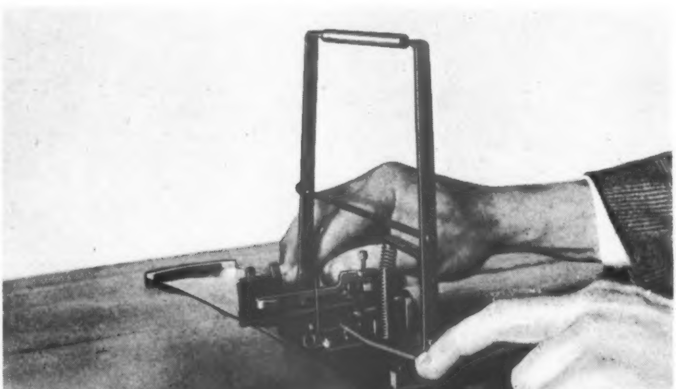


FIG. 13. Aerofoil roughness recorder.

GEAR DESIGN AND PRODUCTION

by E. B. RICHARDSON, M.I.P.E.

(*Abstracted from a paper presented to the Melbourne Section, Institution of Production Engineers,* 11*th July*, 1947.)

When power or motion is transmitted by means of belts, ropes, friction wheels or by chains, we are making use of " gears."

The type of gear we are to discuss tonight, however, is the toothed gear used for the transmission of power. These had their origin in the 19th century, in the wooden cog wheels developed to utilise the power from windmills and water wheels so that the energy of the wheel could be made to do useful work. The reason for the use of gears today is the same underlying factor and the development that has taken place has been necessary to permit ever-increasing speeds and loads brought about by new prime movers and particularly by the increasing use of electric motors and of mechanical aids, a great many of which use gears to make the energy available at the correct part of the machine and at the correct speed of rotation.

The speed ratio of a belt drive is the ratio of the diameters of the driving and driven pulleys. The ratio of a gear drive is given by the ratio of the number of teeth. This is not necessarily the same as the ratio of the diameters of the wheels, and the difference is accounted for by sliding action between the tooth surfaces.

In addition to this sliding which may take place, along the helices of the teeth there is always superimposed a relative sliding motion in the plane of rotation which generally varies in sign in passing through any one tooth mesh. These actions have been minutely studied on mathematical and practical grounds. Edward Sang, professor of mechanical engineering in Constantinople, first suggested that the involute form should be employed for gear teeth and enunciated the law for tooth contact : " If a pair of gears is to transmit uniform angular velocity, the line which lies perpendicular to the tooth surfaces at any point of contact must intersect the pitch line."

Many geometrical forms will meet this requirement, but Professor Sang foresaw the value of the involute profile, and in 1937, before the Royal Scottish Society of Arts, he set forth the advantages of this tooth and the generating method by which they could be achieved.

After a century of gear manufacture, a clearly defined procedure has now emerged which contains the answer to the kinematic

problem, and although development is still taking place in materials and machinery, the major lines of this development are now becoming clear.

Types of Gearwheels.

The main types of gearwheels are grouped according to the relative position of their shafts. For use on parallel shafts, for which cylindrical pitch surfaces are required, there can be used spur gears, single helical gears, and double helical gears. The spur gear is the simplest form of gear, but is relatively noisy at high speeds.

Single Helical Gears.

The single helical gear gives a more satisfactory tooth contact and is therefore quieter, but it needs a thrust bearing for each gear.

Double Helical Gears.

The advantage of the double helical gear over the single helical gear is that it does not set up any end thrust, but conversely, they must not be used where both gears are restrained from endwise movement. Bevel gears are used on shafts whose centre-lines meet, and have conical pitch surfaces.

Straight Bevel Gears.

The pitch of a bevel gear is conventionally measured on the maximum pitch cone radius. The pitch becomes proportionally smaller along the face of the tooth. For this reason bevel gears must be mounted with their outer edges flush and as the gears set up end thrusts on the shafts that carry them, suitable thrust bearings must be provided to hold them in the correct working position. Many bevel gear failures can be attributed to the failure of this correct location.

Spiral Bevel Gears.

Spiral bevel gears bear the same relation to straight bevel gears as helical gears do to spur gears. A variation of the spiral bevel gear is seen in the hypoid gear ; these have conical pitch surfaces but their centre-lines do not meet. Because of this considerably more sliding occurs in hypoid gears.

Perpendicular shafts whose centre-lines do not meet normally require the use of worm gears or spiral gears.

Worm Gears.

In worm gears the worm has a cylindrical pitch surface, but the wormwheel has an enveloping surface giving line contact. A thrust is set up on each supporting shaft. While the endwise position of

the worm can vary without harm, the wormwheel must be located accurately over the worm and any change of position will adversely affect the tooth contact.

If the shafts are not perpendicular and do not meet, spiral gears must be used.

Spiral Gears.

Spiral gears have cylindrical pitch surfaces and are distinguished from single helical gears only by the use to which they are put. The pitch cylinders of spiral gears make only point contact, and have accordingly a small capacity for transmitting power.

Classes of Gear Usage.

When gears are used for large powers at the highest of speeds, as exemplified by the steam turbine drive, the problem of design and manufacture falls into a class of itself.

Turbine Gears.

The illustration (Fig. 1) shows a 4,000 h.p. turbo-alternator connected by gears reducing the speed from 4,750 to 1,000 r.p.m. Referred to as turbine gears, they are the subject of a B.S.I. Specification shortly to be issued. The complexities of this subject can be imagined when it is realised that wheels of this class may weigh ten or fifteen tons, and yet limits of accuracy of the teeth for pitch, shape, and spiral angle must be measured in tenths of a thousandth of an inch. Such gears are invariably of the double helical type, the higher ratios being met by two stages of reduction.

Typical Automotive Gears.

The second class of usage is in the automotive and aircraft field where mass production methods must be employed.

Light weight must be combined with small dimensions and yet permit of large amounts of power being transmitted, although for relatively short periods of time. This requires gears with hardened teeth made from the strongest available materials and leads to a production problem of some complexity.

Manufacturing Drawing of Aircraft Gear.

The problem becomes accentuated in aircraft gears where the specification may read : " For the tooth profile and certain bearing areas to be hardened, while even the ends and tops of the teeth must be left unhardened."

Such gears are made from alloy steel of the highest tensile range, extremely sensitive to heat-treatment and of difficult machinability even in the normalised condition, while after machining the gear must be hardened with a minimum of distortion.

All other gears may be said to fall into a general industrial class of varying degrees of accuracy, type, and size, according to their use. They are the subject of B.S.S. covering 436 : Spur and Helical Gears ; 545 : Bevel Gears ; and 721 : Worm Gears. These specifications are endorsed by the S.A.A., but are not as widely used as would be expected of such important design specifications. Although it is less than 12 years since the earliest of these was published, revisions are at present being considered, covering particularly tooth shape and allowable loadings.

The Form of the Gear Teeth.

It should be recognised that gears essentially work in pairs. Every gear has its mating gear and their teeth must be complementary. With the exception of the worm gear all of the other types have a common shape of tooth and similarity of action provided they are considered in a suitable section.

The phases of engagement of spur gear teeth will illustrate also the other types.

Stages of Engagement of Spur Gears (Fig. 2).

(*a*) The tooth Mark A is on the driving gear, which moves in the direction of the arrow, and B is the tooth on the driven gear with which A will later engage.

(*b*) The first point of contact is between the flank of the driving gear and the tip of the driven gear.

(*c*) From the point a^1/b^1 onwards there occurs a form of rolling contact (but not pure rolling). By the time that the stage represented in C is reached, the respective points of contact a^2 and b^2 have arrived at the pitch point. This corresponds to the instant at which the tooth profiles roll together.

(*d*) From this stage onwards, the points of contact on the respective tooth profiles continue to move over the profiles in the same direction until contact finally ceases at the instant represented by a^3/b^3.

This approach and recession of the tooth contact, combined with rolling and sliding, continues on for every tooth mesh, and by varying the proportions of the teeth, the most desirable contact conditions can be obtained.

The older conception of tooth proportion placed an equal height of tooth above and below the pitch cylinder, this height being 0·318 in. for 1 in. C.P. with a clearance at the root of ·05 in.

Shape of the Standard B.S.S. Rack Tooth (Fig. 3).

It is as a result of much experience with involute teeth that the present standard now recommends the same overall height of tooth with a pressure angle of 20°, and with the clearance increased to allow of a semi-circular clearance curve.

The standard B.S.S. rack tooth form has for unit diametral pitch an addendum of 1,000 and a dedendum of 1,250. This clearance of 0·250 provides for a root fillet of radius of 0·390 in. Although several grades of gear accuracy are provided for in the specification, the tooth shape is the same for all with the exception of the tip modification. This gives a small reduction of metal at the tip of the tooth to ensure that even when the tooth is deflected under load, there will not be a hard bearing at the tip of the tooth.

It should be noted that the picture shows the actual tooth form. A rack cutter to produce equivalent teeth must be made conversely, that is, with rounded tops and a modification from the straight line at the base of the cutter.

Stress Concentration Factor (Fig. 4).

The importance of the fillet curve is shown by the graph giving the relationship of stress intensity to the root radius. While the importance of this factor may vary with the impact loads the gear has to meet, it is clear from the shape of the curve that it is a very significant factor.

For a pinion and wheel designed to be cut on this system the tooth height is not, however, disposed equally above and below the pitch surface, pinions having more tooth height above and wheels less.

Typical Proportions of B.S.I. Wheel and Pinion.

The determination of the amount of profile to be placed above the pitch cylinder is related to the base circles of the two members and the ratio of their numbers of teeth. For the British Standard Rack tooth form, suitable proportions are set out in the specification.

The resulting tooth form gives a well-balanced compromise between strength, resistance to wear, and quietness of running, and is probably superior to any alternative tooth form yet put forward.

Once involute trigonometry is understood, no difficulty is experienced in computing the remaining tooth proportions, although for special cases the degree of correction to be used is sometimes a matter of experience.

The factors which point a good gear design are, firstly, that the size, face width, and materials are suitable for the service. The face width must not be too small in relation to the diameter of the wheel, or so large that the pinion diameter is insufficient to resist the forces causing deflection, or alternatively that the root diameter approaches too closely to the bore. A pitch should then be selected which balances the wear and strength capacity of the gears. The best pitch will accordingly vary with the class of material.

The pitch should be fine enough to give a reasonable number of teeth for the pinion and by so doing to permit the gears to operate

more quietly, although it must be borne in mind that sudden breakage is more to be feared than excessive wear. For this reason, the calculated strength capacity is generally made at least 1½ times the wear capacity.

For double helical gears it is also necessary that the face width be made larger than twice the axial pitch, so that continuous pitch line contact will exist at some part of the face width for every part of the rotation.

In addition, the tooth profile must be designed to give the longest possible length of contact, relative to the pitch, and the greatest radius of curvature to each tooth. This latter point is frequently limited by the pinion tooth having too narrow a land width. In such a case, it is generally preferable to shorten the height of the pinion tooth rather than decrease the value of the correction, which would result in approaching too close to the base circle, or even in undercutting of the profile.

The same general features apply in the case of worm gears, except that the limits are somewhat more stringent owing to the change in profile of the wormwheel teeth at points removed from the centre section.

It should be noted that in all cases, however, it is permissible—in fact, sometimes necessary—that the gears should run at a centre distance different from half the sum of their real pitch diameters.

Considering the standard B.S.I. tooth form, typical proportions are shown for a combination 15 and 114 teeth (Fig. 5.)

The centre distance at which these gears operate is the same as that for conventional gears, but the pinion has a smooth single curve giving the maximum length of contact although it has only 15 teeth. The circle below which undercut would occur is practically coincident with the root circle, while the smooth fillet radius completes a strong tooth.

Section of Worm and Wheel on Offset Plane (Fig. 7).

The complex shape of wormwheel teeth makes it impracticable to produce them by any method other than by generation by a cutter of the same form as the mating worm. In this respect the generation of wormwheel teeth differs from the normal method of producing spur, helical, or bevel gear teeth, for mating gears of these types are each generated by a cutter having a tooth form depending only on the normal base pitch required. One cutter can produce gears of any size provided only that the base pitch is specified.

A hob for generating wormwheel teeth can be used only if the mating worm is of the same essential dimensions as the hob.

Inspection of Gear Teeth.

The B.S.S. previously referred to sets limits of required accuracy for gear profiles to suit different conditions of operation. An accurate profile is, however, of little avail unless it is rotating about the axis of the gear in a truly uniform and concentric manner. The machining of a good gear accordingly commences with the turning of the blank. When the blank is set in the gear cutter it is immaterial whether the outside diameter departs from the nominal by a goodly amount, but it is of importance that it is running truly concentric and that there is no undue run out of the sides of the blank. When machining the blank and cutting the gear, proper consideration should be given to suitable tolerances. Many tables exist giving tooth thickness thinning allowances for different pitches, but no consistent arrangement has been specified for the amount of run-out of the outside diameter, the sides of the gear, and the outside diameter tolerance.

Pitch Tolerances Factor W.

With the aid of a chart which expresses a pitch tolerance factor $W = T + \frac{60}{10P}$, and then taking suitable multiplying factors of W for each element, a consistent practice can be maintained. Suitable multipliers for average work are as follows :

Runout of Outside Diameter	$\frac{1}{2}$ W
Runout of Sides	$\frac{1}{3}$ W
Parallelism of Sides	$\frac{1}{2}$ W
Tolerance for Outside Diameter ...	+ O — 2 W
Allowance for tooth thinning	$1\frac{1}{2}$ W to $2\frac{1}{2}$ W

Normal checking means suffice for all except the measurement of tooth thickness. The most common tool for this purpose is the gear tooth caliper.

Gear Tooth Caliper.

Two vernier scales are set at right angles in a frame, so as to measure a chordal thickness at a given height. The outside diameter of the actual gear must be known, so as to make the necessary allowance for any departure from the calculated diameter. It is usual to measure the thickness of the tooth at its pitch line, but another method is to measure at that point on the gear where it would be in contact with its conjugate rack. At this point, the thickness is the same for a gear of any tooth number, and accordingly no correction need be applied when measuring gears of different numbers of teeth.

Another method is to measure the distance across rolls placed

in opposite tooth spaces. Tables of the required micrometer reading can be set out for an odd or even number of teeth when used with rolls that are a given proportion of the pitch.

Snap Gauge for B.T.L. Measurement.

It is possible to make a snap gauge for measuring the length of the chord which is normal to two selected tooth profiles and tangent to the base circle. The length of this chord may be calculated for any given tooth number. As the tooth surfaces curve away from the maximum length of the chord, the feel is similar to that obtained when measuring a cylinder.

A modern version of this method is an adjustable hand gauge. The hand model B.T.L. gauge is set by slip gauges to the predetermined actual thickness with the micrometer dial set to zero. Any variation can then be read after using the instrument like a micrometer. The distance that is gauged is shown in Fig. 8.

An alternative arrangement uses a bench model instrument (Fig. 9), in which the gear is placed on two horizontal bars and slid against the gauging points. One point is connected by levers to a dial indicator on which can be set maximum and minimum limits. This type is very suitable for the checking of small production work.

The gauging distance for the bench model is the same as for the hand instrument (Fig. 10).

Gear Testing Machine (Fig. 11).

Gears can also be tested by meshing them at close centres under a light spring pressure. If one gear is rotated and the change in centre distance between the gears is measured, it is a good index to the accuracy of the tooth profiles, and of the concentricity of tooth members. A dial indicator gives a visual impression of the errors, but it is even more informative to make a chart record.

Worm Gear Contact Testing Machine.

Wormwheels are difficult to measure and probably the most reliable check is to set them up in a Contact Testing Machine with a previously checked worm. The backlash at correct working centres can then be ascertained, and by blue-marking the worm the contact area can be found. Wormwheels are particularly sensitive to the position of the contact area when in use, and because of the deflections inherent in the gears and their housing, it is usual to make the contact under no-load favour the leaving edge of the wormwheel.

Under increasing loads the contact then moves across towards the centre of the wheel. By this means also, the entering edge of

the wormwheel tooth is left free to allow oil to enter. Although this is the desirable condition, wormwheels are very sensitive to inaccuracies in the hob or deflections while cutting, and it not infrequently occurs that the contact area is not in the desired position.

Machines are available also for the checking of accuracy of the involute profile. The principle of the machine illustrated in Fig. 13 is ingenious and fundamental to the properties of the involute curve. The gear is mounted on an arbor between centres, and a tracing finger connected to a dial indicator rests directly on the profile being tested.

Involute Checker Showing Sine Bar (Fig. 14).

The sine bar is set by means of slip gauges to an angle calculated from the base radius of the gear being tested. As the handle is turned, the carriage carrying the sine bar and the friction is moved ; the friction bar rotates the work and the sine bar has a roller follower which gives a vertical motion to the tracing finger. The tracing thus describes an involute from the base circle of the gear being tested, and any departure is read direct on the dial.

Most machines for this purpose operate from a base disc or the equivalent, which requires a special disc for each gear.

Gear Materials.

The value of a material for use as a gearwheel is determined by its mechanical properties as affecting strength, and by its physical properties and chemical analysis as regards wearing ability. This ability to resist surface abrasion and the fatigue of the surface by pitting, although primarily related to surface hardness, is also influenced by the analysis of the steel and the characteristics brought about by different heat-treatments. A very good idea of allowable stress values is given by the charts published in the latest spur gear specification.

Mechanical properties alone are not a safe guide to satisfactory performance. For instance, for a wormwheel a 10 per cent. to 12 per cent. tin bronze is by far the most satisfactory material. Most other bronzes, even of higher tensile strength, have much lower load capacities. Any material, other than bronze, has been found to have unsuitable properties at speeds other than given by hand operation, or for cast iron a rubbing speed at about 500 feet per minute. Efforts have accordingly been made to improve the properties of those materials which have proved satisfactory, and one of the significant developments in this direction is the use of

centrifugal castings. When applied to a bronze wormwheel, the most notable effect is a change in the structure, both in the final distribution of the eutectoid and the reduced grain size (Fig. 15).

Successful centrifugal castings in both cast iron and steel have also been produced.

When all these factors have been attended to, satisfactory power transmission will result only if the gears are mounted in well-designed housings, and supported on sufficiently rigid shafts in bearings of ample capacity and with correct lubrication conditions.

Balance in Tooth Design.

The art of generating gear teeth and other forms is often insufficiently appreciated. A balanced tooth design can be achieved with no more cost and only a little more trouble than a poor tooth.

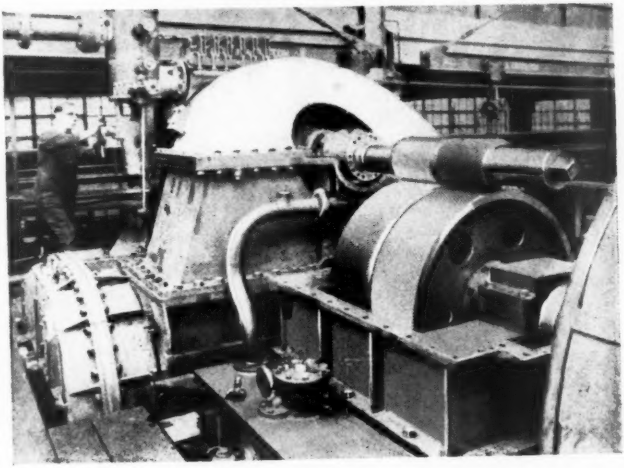


FIG. 1.

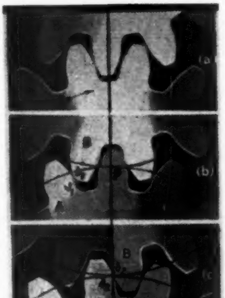


FIG. 2.

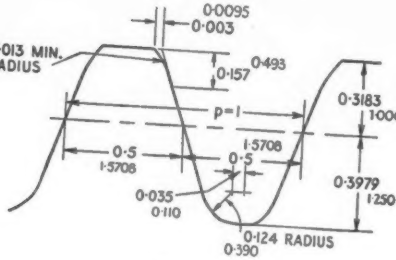


Fig. 3.

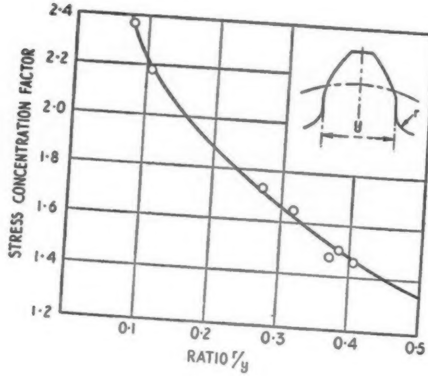


Fig. 4.

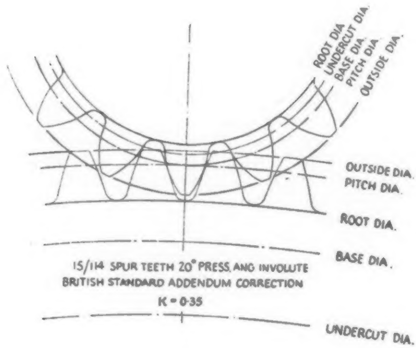


Fig. 5.

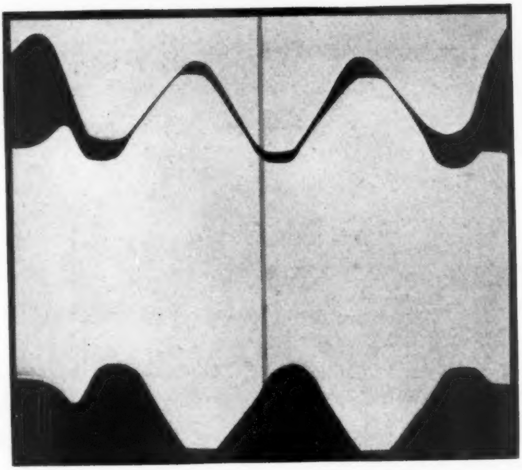


Fig. 6.

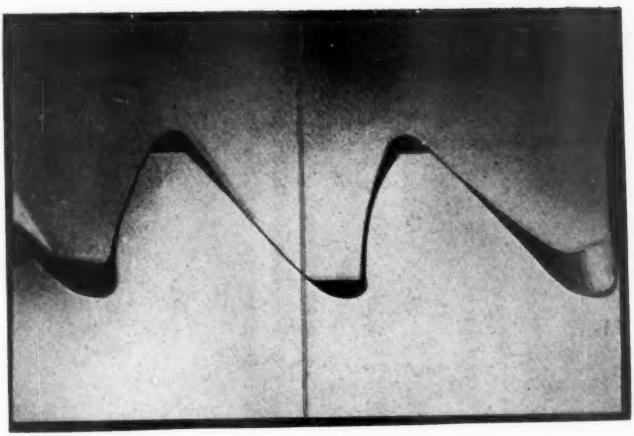


Fig. 7.

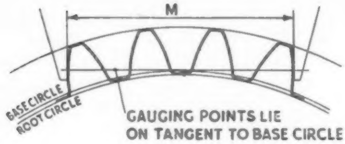


FIG. 8.

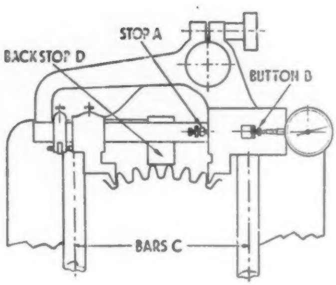


FIG. 9.

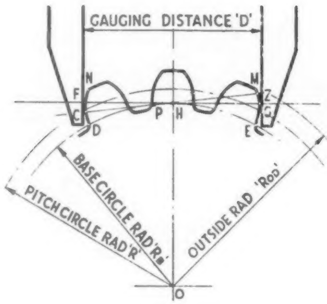


FIG 10.

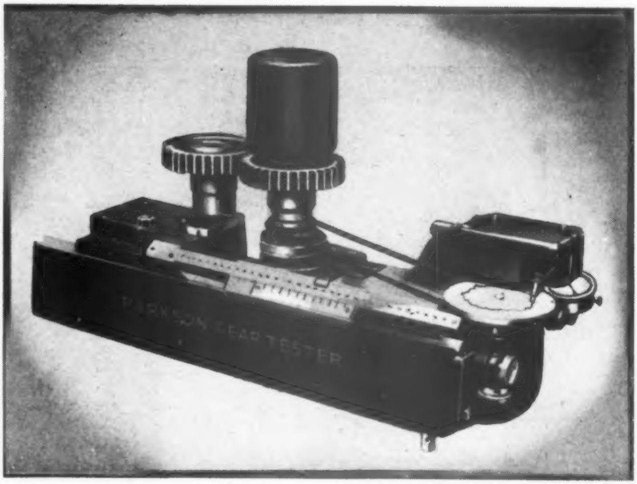


FIG. 11.

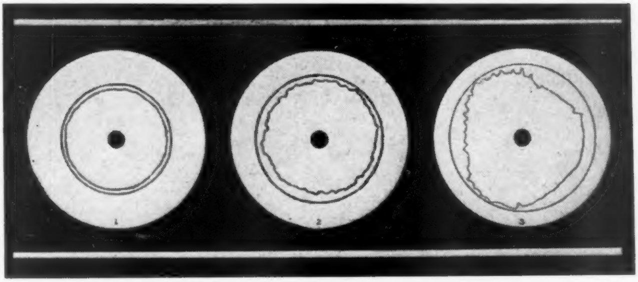


FIG. 12. Chart 1 is from a highly accurate gear. Chart 2 shows gears with some profile irregularity. Chart 3 shows gears of which one is eccentric.

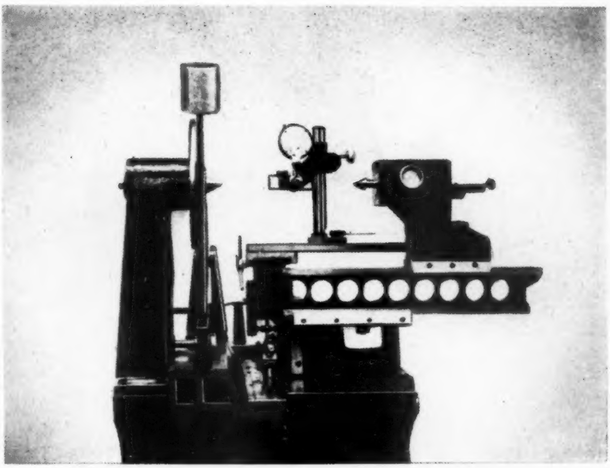


FIG. 13.

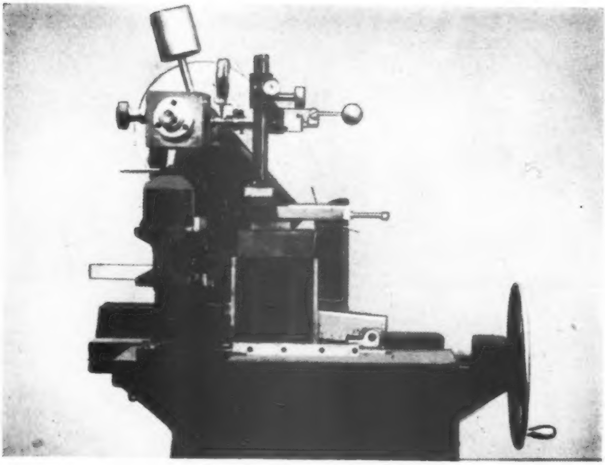


FIG. 14.

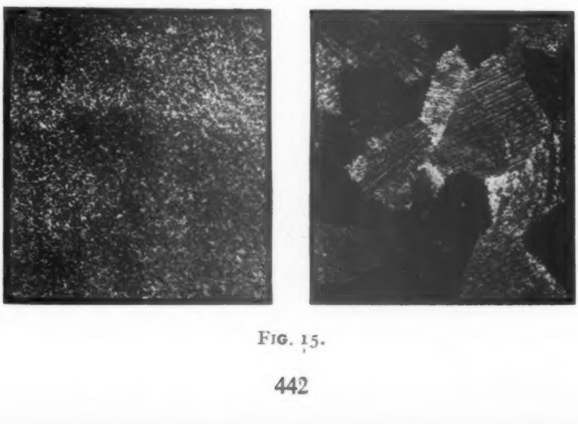


FIG. 15.

AN ENGINEER'S APPROACH TO THE SELECTION OF TOOL MATERIALS

by JOHN M. PETHEBRIDGE, A.M.I.E. (Aust.).

(*Abstracted from a paper presented to the Melbourne Section, Institution of Production Engineers,* 13*th March*, 1946.)

When first I was asked to talk to you about Tool Steels and their selection, I doubted whether the subject was one capable of commanding sufficient interest on the part of Production Engineers to make it worthy of a place in your syllabus. On attempting to analyse my doubts, I had to confess to myself that what really was in doubt was not the subject itself but my own ability adequately to deal with it, from your point of view.

I may therefore be pardoned, perhaps, if at the outset I make it clear that I am assuming your outlook to be that of Production Engineers who conform, more or less, to the definition recently given by one of your English members, and passed on to me by your President :

> " A trained engineer capable of setting in motion, driving and controlling the many forces required in an engineering works to make—
>
> (*a*) what is required ;
>
> (*b*) when it is required ;
>
> (*c*) at a profit, and at a price the client will pay."

Actually, from the wide variety of tool steels and other tool materials available, the selection of an appropriate material for a particular tool is often, to say the least, a very haphazard process. It is sometimes left to the Draughtsman who, not infrequently, dodges the issue by calling for " Tool Steel," " Punch Steel," "Die Steel," or, in a burst of self-confidence, " High Speed Steel." The decision is then, at best, left to the Heat-Treater or someone in the Toolroom, who will generally select a type and brand believed from his own experience to be suitable. This method of selection must be acknowledged to give, in many cases, and according to the intelligence and experience of the man concerned, a reasonably good result—often good enough to justify the Production Engineer's belief that this particular problem presents no headaches, and that he can devote his full attention to the multitudinous other factors which may " go sour " and upset his schedule. Nevertheless, superficially similar operations frequently reveal, on close analysis, essential differences which one cannot blame a tradesman for missing.

The Basis of Selection.

A tool is a mechanical contrivance for cutting, forming or otherwise "working" a piece of material which we may call the component. In operation, stresses are set up, both in tool and component. The stresses in the component obviously must be of sufficient magnitude to cause mechanical failure of one kind or another; the resultant stresses in the tool must *not* cause failure, and, moreover, must not be of such a nature of or such magnitude that the life of the tool is unduly shortened by abrasion, fatigue, or avoidable change in mechanical properties through overheating.

Much can be done to achieve these results by good tool design; by fixing upon a physical form or shape that will minimise the value of tool stresses and cause them to occur in the least harmful direction; by attention to surface finish, and the provision of cooling facilities. After all this has been done, we are left with a piece of tool material in which there are stresses of a magnitude we do not know but can ascertain in a relative sense, and whose direction we do know, or can easily find out if we analyse the operation.

The next task is to select our tool material. We are in a position to say what we want, and to find the answer to such questions as: Do we want a tool that will stand up to crushing stresses, to tensile or bursting stresses; is a keen, hard edge required, and is this edge likely to become very hot in operation? Is the duty one which involves a lot of rubbing, calling for a material which will offer good resistance to abrasive wear? In other words, we must analyse the operation to be performed by the tool, so as to know with certainty the nature and approximate direction of the stresses and the general conditions to be withstood. We must also form an idea of their magnitude, relative to each other and to those involved in other operations within our experience; in the absence of any quantitative standard, a classification into one or other of five degrees of magnitude—Very Light, Light, Medium, Heavy, and Very Heavy—is quite useful.

Speaking generally, stresses can be classed as tensile, compressive, shearing or torsional. Tensile stresses, mainly, are involved when the operation tends to bend the tool, or to burst it as for example in the usual forming or drawing die. Crushing loads come into the category of compressive stresses, sometimes with an element of shear; while pure shearing or torsional stresses are seldom met with (apart from in twist drills and reamers), except in tools of a more or less complex type. Loading may be constant, intermittent or reversible (the last condition is sometimes very important), while rigidity and frictional conditions, with all their consequences, require consideration.

It is a very frequent occurrence for stress conditions in a tool to

be of a complex nature. One part may be in compression while another is in tension ; or tensile stresses, calling for more " toughness " than is possessed by extremely hard materials, may be and often are associated with severe abrasive tendencies. Rigidity in the tool is sometimes of paramount importance ; even a comparatively small elastic deformation may, under heavy intermittent loading, cause early failure through fatigue, and in this connection it is important to remember that all tool steels, whatever their composition and whether in the soft or hard state, have substantially the same modulus of elasticity. This means that substitution of a harder for a softer tool steel will not make a given tool any stiffer ; it may not fail so soon through fatigue, but all the other bad effects of lack of rigidity—chatter, dimensional variations and so forth—will be quite unaffected. The occasional operation where " springiness " in a tool is desirable—certain lathe tools, for example—is well enough known to workshop men, and in the present discussion it may be assumed that rigidity is *always* desirable in a tool. I only mention this point to draw attention to the fact that this is, in nearly all cases, a matter of tool design, not of material selection.

Tool Steels.

Tool Steels may be classified in several ways Metallurgically, they fall into one or other of two main groups, Plain Carbon Steels and Alloy Steels, with some occasional difference of opinion as to how much of certain alloying elements is necessary to shift a steel from the first group to the second.

They may also be classified according to the purposes for which they are designed or may be used, e.g., Punch Steels, Die Steels, Chisel Steels, Hot Die Steels and so on. On the whole, this method has little to recommend it ; from the point of view I am endeavouring to put before you it has no virtues, and is more inclined to be misleading than useful.

Since it is obvious that there must be a sufficient margin of hardness, in favour of the tool, over the material being worked, a classification according to hardness could be attempted but would not tell very much. Unfortunately, as measured by one of the common indentation testing machines, hardness is only one property among many and gives no hint of certain essential differences between equally hard steels of different types.

Heat-treaters classify tool steels as either water-hardening or oil-hardening. This is substantially the same as the preliminary grouping I prefer, namely, into *Shallow-Hardening* and *Deep-Hardening Steels ;* I prefer these terms, as being descriptive of properties rather than of methods.

The shallow-hardening steels are comparatively cheap to purchase, easy to machine in the annealed condition and to grind after harden-

ing, and capable of a very efficient heat-treatment by simple methods and inexpensive equipment. By intelligent tempering after hardening, combined with experienced selection as regards carbon content, a wide range of properties can be obtained, subject always to the fundamental fact that the steels *are* shallow-hardening and, except in the smallest cross-sections, possess a relatively soft core. (This, of course, is sometimes a definite advantage.)

Conclusion.

I do not propose even to mention the many ways by which a variety of properties can be obtained simultaneously in a single tool: any such attempt would speedily become a lecture on heat treatment, which is quite beyond the scope of this address. With experience, the engineer will become familiar with such matters, and so greatly enrich his field of selection of tool materials.

It is obviously impossible, in a short address like this, to consider all the factors which experience teaches one to consider in selecting tool steels, but I hope that, at least, I have been able to give you some food for thought, and have not completely let down those who so kindly invited me to address you.

DIAMONDS AND DRESSING DEVICES FOR THREAD GRINDING

by J. FORSYTHE.

(*Abstracted from a paper presented to the Melbourne Section, Institution of Production Engineers*, 13*th February*, 1947.)

Since the great majority of Dressing Devices used on Thread Grinding Machines depend on diamonds of various forms and shapes, it would be helpful and interesting to consider briefly some of the problems that have had to be overcome in the diamond trade to ensure the necessary supply after having established the fact that diamonds for this purpose could be used economically.

Historical.

It is fairly well known that diamonds are found principally in South and South-West Africa, The Congo, British Guiana and Brazil. It is not, however, so well known that diamonds are produced in Australia where the main fields are : Stanthorpe, in Queensland, Beechworth, in Victoria, Capertee and Cudgegong, near Mudgee, and Capeton, near Inverell, in N.S.W.

Different mines and fields produce diamonds with certain characteristics which enable the diamond expert to identify them and the source from which they have come, and it is possible that, in such an examination, a certain known characteristic may be sufficient to permit of the selection of a stone for a given purpose.

It is of interest to note that the hardest stones come from the Inverell field in N.S.W. and provided that the stone is not deficient in other necessary qualities, will give the most satisfactory results per carat when used for the dressing of the fine grit wheels generally used for thread grinding.

Prior to the invasion of Holland, which was the centre of the diamond trade, there was comparatively little interest in the diamond industry in the British Empire but the necessity of becoming self-supporting to meet the growing demand has brought about a huge expansion in this field and the opinion has been expressed that in the post-war period the centre of importance in the diamond trade may well become permanently situated in Britain.

In normal times it was estimated that 350 tons of rock had to be removed and processed to obtain 46 carats of diamonds. About 50 per cent. of the stones produced were used as gems. Under wartime conditions, however, practically the whole of the world's output is being diverted to industry, and as this is estimated at

approximately 2 tons per annum totalling 10 million carats, some idea can be formed of the importance of the industry and the useful part that it played in the war effort.

Formation.

The diamond consists of pure carbon and is one of the hardest substances known to man. As already stated the quality of hardness varies in stones from various sources and this quality in conjunction with other factors such as size, shape, and grain flow must be taken into consideration by the expert in making his selection of stones for various purposes.

Generally speaking, brown-coloured diamonds are more subject to flaws than the light yellow or white varieties, and these latter are used principally for the formed and shaped diamonds required in the dressing devices of thread grinding machines.

Perhaps the most important quality to be studied before cutting and shaping a stone is grain flow. Fig. 1 illustrates the natural crystallisation of a diamond showing the " grain flow " in the four " regular " shapes. All other shapes are known as " irregular " but are always derived from these shapes and it is this factor which enables the expert to make his selection. The grain flow is not always easy to determine but once fixed it simplifies the cutting and forming of the stone. When consideration is given to the wide field of use for industrial diamonds such as dressers for emery wheels, trueing tools for profiling grinding wheels, turning and boring tools for metals and plastics, wire drawing dies, rock drilling, glass cutting and drilling, and bearings for chronometers and scientific instruments, it will be readily seen that the expert can generally find an appropriate use for any grain of stone provided the quality is good and when the latter characteristic is lacking, the stone can be crushed to various meshes for impregnated laps and other purposes.

Selection of Diamonds.

Sufficient has been said to make it evident that the selection of a stone for any given purpose is a matter for the diamond expert, but some knowledge of the correct application of the diamond tool is necessary for economical use to be made of it. The unit of weight in the diamond trade is the " carat " which equals one-fifth of a gram and, in order to get the best results from a mounted stone, care should be exercised to ensure that it is not too light in weight for the work it is expected to do. This is especially important in the dressing of grinding wheels.

Fig. 2 illustrates the relative difference in stones by weight ranging from ½ to 8 carats. Being of irregular shape renders it

difficult to quote sizes, but in stones of reasonably regular shape the average size would be approximately ·115 in. for the ½ carat and about ·325 in. for the 8 carat.

Diameter of Wheel in Inches	Face of Wheel in Inches	Weight of Diamond in Carats, from :	Diameter of Wheel in Inches	Face of Wheel in Inches	Weight of Diamond in Carats, from:
4	½	0·25	14	1½	1·25
6	½	0·33	16	1½	1·30
6	¾	0·40	18	1½	1·50
8	1	0·50 to 0·60	20	2	2·00
8	2	0·60 to 0·75	22	2	2·00
10	1	0·80 to 1·00	24	2	2·25
10	1½	1·00 to 1·25	24	3	2·50
12	1	1·00	26	4	3·50

FIG. 3.

Fig. 3 gives a table for the selection of diamonds by weight for dressing grinding wheels of various sizes. It will be noted that the table does not take into consideration either the grit or grade of the wheel and these factors also have some bearing on the economical use of the diamond. This table is in fairly common use for ordinary cylindrical, surface, and cutter grinding, but when applied to thread grinding it is advisable to add approximately 50 per cent. to the diamond weight specified for any particular wheel size to offset the finer grit and harder grade.

Fig. 4 illustrates the method of application of the diamond to the wheel. The angles of 5° to 15° are covered over a series of dressings and at the same time the mount is rotated in the holder frequently thus ensuring a sharp facet being presented to the wheel at each dressing. In thread grinding this method only applies to the first rough dressing across the face and down both sides of the wheel prior to balancing or when removing an existing profile from the face of a wheel.

Special Thread-Grinding Diamonds.

In order to ensure the most economical use of diamonds for dressing thread profiles great care is necessary on the part of the operator. Diamonds for this purpose can not of course be selected by weight and in some cases for fine pitches the diamond point

presented to the wheel must necessarily be very small and consequently fragile. Great care therefore must be exercised both in the primary selection and mounting of the stone by the diamond merchant and the manner of presentation to the wheel by the operator.

Fig. 5 illustrates a variety of mounted stones used in manually operated dressing devices for thread grinding.

A = Diamond used in device of Swiss thread correcting lathe.

B = Roughing Diamond used on Swiss Toolroom Model machine.

C = Finishing diamond for same machine.

D = Splinter diamond for cresting wheel for Whitworth or similar form.

Fig. 6 illustrates some mounted stones used on mechanically operated dressing devices.

A^1 = Ball point diamond used for profiling Whitworth form on multi-ribbed wheel " Matrix " device.

B^1 = Radius formed diamond used to profile single point wheel for Whitworth form on Jones and Lamsen machine.

C^1 = Chisel point diamond used in multi-ribbed wheel dresser of " Newall " thread grinding machine.

The reason for the variety of forms shown will become evident when consideration is given to the various types of dressing devices.

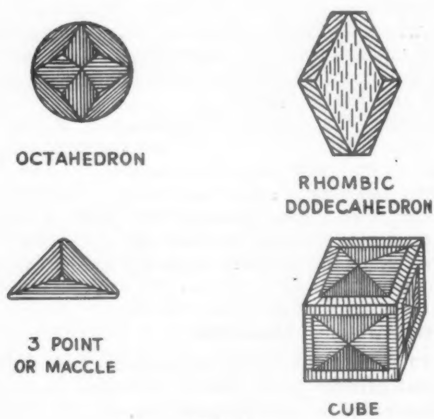


FIG. 1.

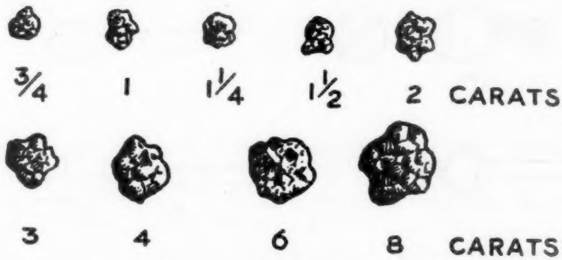

3/4
1
1 1/4
1 1/2
2 CARATS
3
4
6
8 CARATS

FIG. 2.

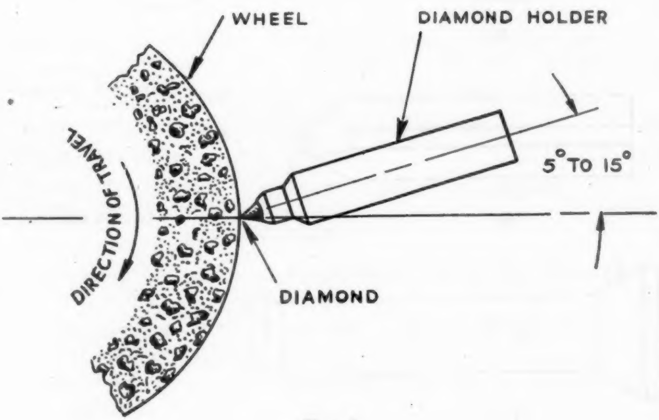

WHEEL
DIAMOND HOLDER
DIRECTION OF TRAVEL
5° TO 15°
DIAMOND

FIG. 4.

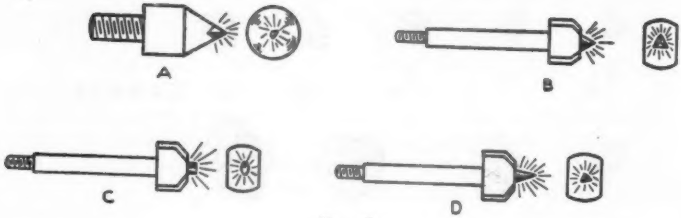


FIG. 5.

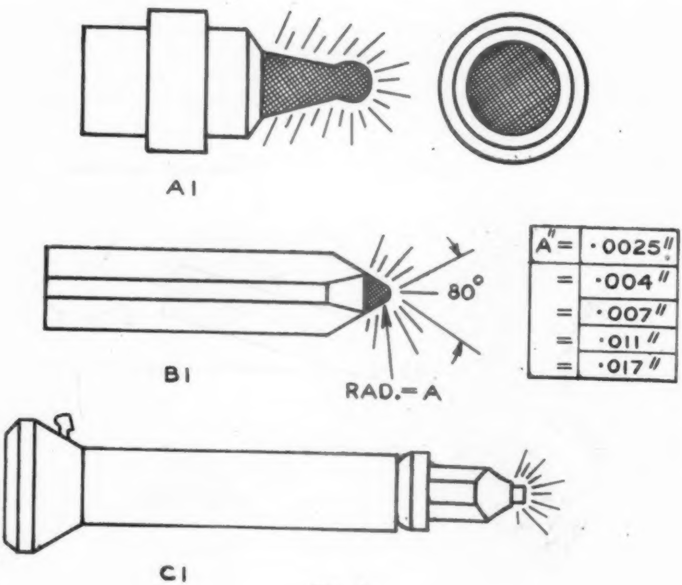


FIG. 6.

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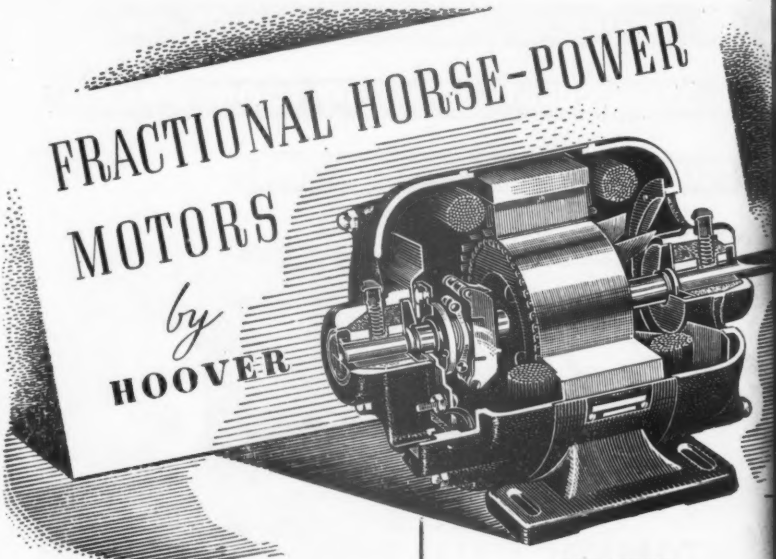

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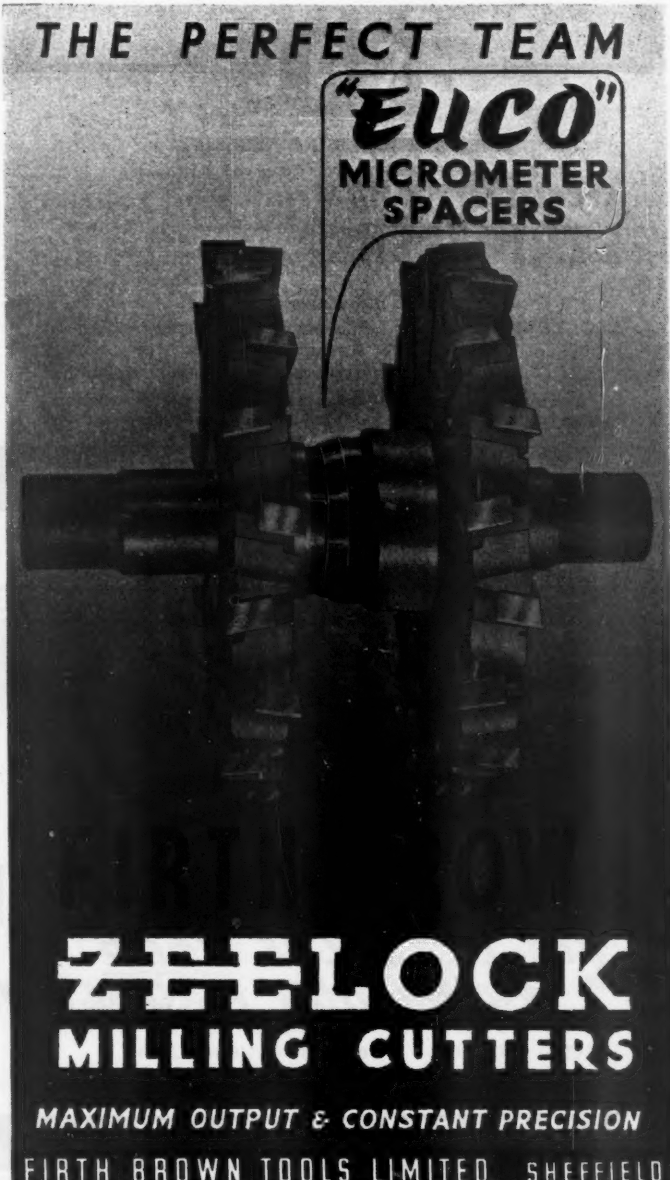
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